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UNITED STATES PATENT APPLICATION

FOR

APPARATUS AND METHOD FOR PATIENT ROUNDING WITH A REMOTE  
CONTROLLED ROBOT

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## REFERENCE TO CROSS-RELATED APPLICATIONS

This application is a continuation-in-part of Application No. 10/206,457, filed on July 25, 2002, pending.

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## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The subject matter disclosed generally relates to the field of robotics.

### 2. Background Information

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Patient consultation is a critical component of medical care. For example, it is typically imperative that a physician visit a patient after a surgical procedure. Such visits not only allow the physician to observe the patient for follow-up care, but aids in establishing the all

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important personal relationship between doctor and patient. Because of various economic and regulatory issues it has become increasing difficult for physicians to develop strong relationships with patients through interactive visits.

John Hopkins Medical Institution has tested a program where tele-conferencing equipment is placed in a patient's room. The doctor can then remotely "visit" the patient through the tele-conferencing system. Such an approach  
5 would require tele-conferencing equipment in each patient room, thereby increasing the cost of equipping and maintaining the medical facility. Additionally, the tele-conferencing equipment must be placed in a position to allow the doctor to view the patient. This may be in a  
10 location adjacent to the patient's bed. Such a location may not allow the doctor to view an ambulatory patient.

Robots have been used in a variety of applications ranging from remote control of hazardous material to assisting in the performance of surgery. For example, U.S.  
15 Patent No. 5,762,458 issued to Wang et al. discloses a system that allows a surgeon to perform minimally invasive medical procedures through the use of robotically controlled instruments. One of the robotic arms in the Wang system moves an endoscope which has a camera that  
20 allows a surgeon to view a surgical area of a patient.

Tele-robots such as hazardous waste handlers and bomb detectors may contain a camera that allows the operator to view the remote site. Canadian Pat. No. 2289697 issued to Treviranus, et al. discloses a videoconferencing platform  
5 that has both a camera and a monitor. The Treviranus patent also discloses embodiments with a mobile platform, and mechanisms for moving the camera and the monitor.

Publication Application No. US-2003-0050233-A1  
discloses a remote robotic system wherein a plurality of  
10 remote stations can control a plurality of robotic arms used to perform a minimally invasive medical procedure. Each remote station can receive a video image provided by the endoscope inserted into the patient. The remote stations are linked to the robotic system by a dedicated  
15 communication link.

To date there has not been a utilization of mobile robots to allow a doctor to remotely visit a patient. Such a technique would allow more frequent doctor/patient visits and improve the quality of medical care.

### BRIEF SUMMARY OF THE INVENTION

A method for remotely monitoring a patient with a robot that has a camera and a microphone. A robot input command is generated and transmitted from a remote station. The  
5 robot input command is received by the robot. The robot moves in response to the robot input command. A video image and sound of the patient is transmitted to the remote station from the robot.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 is an illustration of a robotic system;

Figure 2 is a schematic showing movement of a robot in  
a medical facility;

5        Figure 3 is a schematic of an electrical system of a  
robot;

Figure 4 is a further schematic of the electrical  
system of the robot;

Figure 5 is side view of the robot;

10       Figure 6 is a top perspective view of a holonomic  
platform of the robot;

Figure 7 is a side perspective view of a roller  
assembly of the holonomic platform;

15       Figure 8 is a bottom perspective view showing a  
pedestal assembly of the robot;

Figure 9 is a sectional view showing an actuator of the  
pedestal assembly;

Figure 10 is a side view of a robot head.

## DETAILED DESCRIPTION

Disclosed is a method for remotely monitoring a patient. The method includes generating and transmitting input commands to the robot from a remote station. The remote station may include a personal computer that is operated by a doctor. The input commands can move the robot so that a video image and sounds of the patient can be captured by a robot camera and microphone, respectively, and transmitted back to the remote station. The robot may also have a monitor and a speaker to allow for two-way videoconferencing between the patient and a doctor at the remote station. The robot can move from room to room so that a doctor can make "patient rounds" within a medical facility. The system thus allows a doctor to visit patients from a remote location, thereby improving the frequency of visits and the quality of medical care.

Referring to the drawings more particularly by reference numbers, Figure 1 shows a robotic system 10. The robotic system 10 includes a robot 12, a base station 14 and a remote control station 16. The control station 16 may be coupled to the base station 14 through a network 18.

By way of example, the network 18 may be either a packet switched network such as the Internet, or a circuit switched network such as a Public Switched Telephone Network (PSTN) or other broadband system. The base station 5 14 may be coupled to the network 18 by a modem 20 or other broadband network interface device.

The remote control station 16 may include a computer 22 that has a monitor 24, a camera 26, a microphone 28 and a speaker 30. The computer 22 may also contain an input 10 device 32 such as a joystick or a mouse. The station 16 is typically located in a place that is remote from the robot 12. Although only one robot 12 is shown, it is to be understood that the system 10 may have a plurality of robots 12. In general any number of robots 12 may be 15 controlled by any number of remote stations. For example, one remote station 16 may be coupled to a plurality of robots 12, or one robot 12 may be coupled to a plurality of remote stations 16.

The robot 12 includes a movement platform 34 that is 20 attached to a robot housing 36. Also attached to the robot housing 36 are a camera 38, a monitor 40, a microphone(s)



42 and a speaker 44. The microphone 42 and speaker 30 may create a stereophonic sound. The robot 12 may also have an antenna 45 that is wirelessly coupled to an antenna 46 of the base station 14. The system 10 allows a user at the remote control station 16 to move the robot 12 through the input device 32. The robot camera 38 is coupled to the remote monitor 24 so that a user at the remote station 16 can view a patient. Likewise, the robot monitor 40 is coupled to the remote camera 26 so that the patient can view the user. The microphones 28 and 42, and speakers 30 and 44, allow for audible communication between the patient and the user.

Each remote station computer 22 may operate Microsoft OS software and WINDOWS XP or other operating systems such as LINUX. The remote computer 22 may also operate a video driver, a camera driver, an audio driver and a joystick driver. The video images may be transmitted and received with compression software such as MPEG CODEC.

The system 10 may be the same or similar to a robotic system sold by the assignee InTouch-Health, Inc. of Santa Barbara, California under the trademark COMPANION.

Figure 2 shows an implementation of the system in a medical facility 50. The medical facility 50 may be a hospital, assisted living home, etc, that contains a plurality of patient rooms 52, including a first patient room 52A and a second patient room 52B, each containing one or more patients.

A doctor may be located at a remote station 16. The remote station 16 may be on or off the premises of the medical facility 50. The station 16 is linked to the robot 12 by the network 18 and wireless base station 14. The medical facility 50 may have a number of wireless base stations 14 located throughout the facility 50 so that the robot 12 is always linked to a station 14.

The system 10 allows the doctor to make patient rounds in the facility 50. For example, the doctor may generate robot input commands at the remote station 16 that are then transmitted and received by the robot 12. The input commands may cause the robot to move to the door of the first patient room 52A. The doctor can view a chart 54 outside the room through the robot camera. The doctor may utilize a zoom feature of the camera to read the chart.

After reading the chart the doctor may move the robot into the first patient room 52A. The system allows the doctor to conduct a two-way videoconference with the patient. The videoconference may allow the doctor to  
5 observe the patient through the robot camera. The doctor can also ask questions that can be generated by the robot speaker and/or displayed by the robot monitor. The robot monitor can display the doctor at the remote station so that the patient feels they are being "visited" by the  
10 doctor.

After the visiting the patient in the first patient room 52A the doctor can move the robot 12 to the second patient room 52B where the process is repeated. The system thus allows the doctor to visit multiple patients from a  
15 remote location. This increases the frequency of doctor visits, reduces doctor fatigue and improves the overall medical care of the patients.

Figures 3 and 4 show an embodiment of the robot 12. The robot 12 may include a high level control system 150  
20 and a low level control system 152. The high level control system 150 may include a processor 154 that is connected to

a bus 156. The bus 156 is coupled to the camera 38 by an input/output (I/O) port 158, and to the monitor 40 by a serial output port 160 and a VGA driver 162. The monitor 40 may include a touchscreen function that allows the patient to enter input by touching the monitor screen 40.

The speaker 44 is coupled to the bus 156 by a digital to analog converter 164. The microphone 42 is coupled to the bus 156 by an analog to digital converter 166. The high level controller 150 may also contain random access memory (RAM) device 168, a non-volatile RAM device 170 and a mass storage device 172 that are all coupled to the bus 162. The mass storage device 172 may contain medical files of the patient that can be accessed by the user at the remote control station 16. For example, the mass storage device 172 may contain a picture of the patient. The user, particularly a health care provider, can recall the old picture and make a side by side comparison on the monitor 24 with a present video image of the patient provided by the camera 38. The robot antennae 45 may be coupled to a wireless transceiver 174. By way of example, the

transceiver 174 may transmit and receive information in accordance with IEEE 802.11b.

The controller 154 may operate with a LINUX OS operating system. The controller 154 may also operate MS  
5 WINDOWS along with video, camera and audio drivers for communication with the remote control station 16. Video information may be transceived using MPEG CODEC compression techniques. The software may allow the user to send e-mail to the patient and vice versa, or allow the patient to  
10 access the Internet. In general the high level controller 150 operates to control the communication between the robot 12 and the remote control station 16.

The high level controller 150 may be linked to the low level controller 152 by serial ports 176 and 178. The low  
15 level controller 152 includes a processor 180 that is coupled to a RAM device 182 and non-volatile RAM device 184 by a bus 186. The robot 12 contains a plurality of motors 188 and motor encoders 190. The encoders 190 provide feedback information regarding the output of the motors  
20 188. The motors 188 can be coupled to the bus 186 by a digital to analog converter 192 and a driver amplifier 194.

The encoders 190 can be coupled to the bus 186 by a decoder 196. The robot 12 also has a number of proximity sensors 198 (see also Fig. 1). The position sensors 198 can be coupled to the bus 186 by a signal conditioning circuit 200 and an analog to digital converter 202.

The low level controller 152 runs software routines that mechanically actuate the robot 12. For example, the low level controller 152 provides instructions to actuate the movement platform to move the robot 12. The low level controller 152 may receive movement instructions from the high level controller 150. The movement instructions may be received as movement commands from the remote control station. Although two controllers are shown, it is to be understood that the robot 12 may have one controller controlling the high and low level functions.

The various electrical devices of the robot 12 may be powered by a battery(ies) 204. The battery 204 may be recharged by a battery recharger station 206 (see also Fig. 1). The low level controller 152 may include a battery control circuit 208 that senses the power level of the battery 204. The low level controller 152 can sense when

the power falls below a threshold and then send a message to the high level controller 150. The high level controller 150 may include a power management software routine that causes the robot 12 to move so that the  
5 battery 204 is coupled to the recharger 206 when the battery power falls below a threshold value.

Alternatively, the user can direct the robot 12 to the battery recharger 206. Additionally, the battery 204 may be replaced or the robot 12 may be coupled to a wall power  
10 outlet by an electrical cord (not shown).

Figure 5 shows an embodiment of the robot 12. The robot 12 may include a holonomic platform 210 that is attached to a robot housing 212. The holonomic platform 210 provides three degrees of freedom to allow the robot 12  
15 to move in any direction.

The robot 12 may have a pedestal assembly 214 that supports the camera 38 and the monitor 40. The pedestal assembly 214 may have two degrees of freedom so that the camera 26 and monitor 24 can be swiveled and pivoted as  
20 indicated by the arrows.

As shown in Figure 6 the holonomic platform 210 may include three roller assemblies 220 that are mounted to a base plate 221. The roller assemblies 220 allow for movement in any direction.

5       The robot housing 212 may include a bumper 222. The bumper 222 may be coupled to optical position sensors 223 that detect when the bumper 222 has engaged an object. After engagement with the object the robot can determine the direction of contact and prevent further movement into  
10 the object.

Figure 7 shows an embodiment of a roller assembly 220. Each assembly 220 may include a drive ball 224 that is driven by a pair of transmission rollers 226. The assembly 220 may include a retainer ring 228 and a plurality of  
15 bushings 230 that capture and allow the ball 224 to rotate in x and y directions but prevent movement in a z direction. The assembly also holds the ball under the transmission rollers 226.

The transmission rollers 226 are coupled to a motor  
20 assembly 232. The assembly 232 corresponds to the motor 188 shown in Fig. 4. The motor assembly 232 includes an



output pulley 234 attached to a motor 236. The output pulley 234 is coupled to a pair of ball pulleys 238 by a drive belt 240. The ball pulleys 238 are each attached to a transmission bracket 242. The transmission rollers 226  
5 are attached to the transmission brackets 242.

Rotation of the output pulley 234 rotates the ball pulleys 238. Rotation of the ball pulleys 238 causes the transmission rollers 226 to rotate and spin the ball 224 through frictional forces. Spinning the ball 224 will move  
10 the robot 12. The transmission rollers 226 are constructed to always be in contact with the drive ball 224. The brackets 242 allow the transmission rollers 226 to freely spin in a direction orthogonal to the driven direction when one of the other roller assemblies 220 is driving and  
15 moving the robot 12.

As shown in Figure 8, the pedestal assembly 214 may include a motor 250 that is coupled to a gear 252 by a belt 254. The gear 252 is attached to a shaft 256. The shaft 256 is attached to an arm 258 that is coupled to the camera  
20 38 and monitor 40 by a bracket 260. Activation of the motor 250 rotates the gear 252 and sleeve 256, and causes

the camera 38 and monitor 40 to swivel (see also Fig. 5) as indicated by the arrows 4.

As shown in Figure 9, the assembly 214 may further include a tilt motor 262 within the arm 258 that can cause the monitor 40 and camera 38 to pivot as indicated by the arrows 5. The tilt motor 262 may rotate a worm 264 that rotates a worm gear 266. The pin 268 is rigidly attached to both the worm gear 266 and the bracket 260 so that rotation of the gear 266 pivots the camera 38 and the monitor 40. The camera 38 may also include a zoom feature to provide yet another degree of freedom for the operator.

The robot 10 may be controlled by a number of different doctors. To accommodate for this the robot may have an arbitration system. The arbitration system may be integrated into the operating system of the robot 12. For example, the arbitration technique may be embedded into the operating system of the high-level controller 150.

By way of example, the users may be divided into classes that include the robot itself, a local user, a caregiver, a doctor, a family member, or a service provider. The robot 12 may override input commands that

conflict with robot operation. For example, if the robot runs into a wall, the system may ignore all additional commands to continue in the direction of the wall. A local user is a person who is physically present with the robot.

- 5 The robot could have an input device that allows local operation. For example, the robot may incorporate a voice recognition system that receives and interprets audible commands.

A caregiver is someone who remotely monitors the  
10 patient. A doctor is a medical professional who can remotely control the robot and also access medical files contained in the robot memory. The family and service users remotely access the robot. The service user may service the system such as by upgrading software, or  
15 setting operational parameters.

Message packets may be transmitted between a robot 12 and a remote station 16. The packets provide commands and feedback. Each packet may have multiple fields. By way of example, a packet may include an ID field a forward speed  
20 field, an angular speed field, a stop field, a bumper

field, a sensor range field, a configuration field, a text field and a debug field.

The identification of remote users can be set in an ID field of the information that is transmitted from the remote control station 16 to the robot 12. For example, a user may enter a user ID into a setup table in the application software run by the remote control station 16. The user ID is then sent with each message transmitted to the robot.

The robot 12 may operate in one of two different modes; an exclusive mode, or a sharing mode. In the exclusive mode only one user has access control of the robot. The exclusive mode may have a priority assigned to each type of user. By way of example, the priority may be in order of local, doctor, caregiver, family and then service user. In the sharing mode two or more users may share access with the robot. For example, a caregiver may have access to the robot, the caregiver may then enter the sharing mode to allow a doctor to also access the robot. Both the caregiver and the doctor can conduct a simultaneous tele-conference with the patient.

The arbitration scheme may have one of four mechanisms; notification, timeouts, queue and call back. The notification mechanism may inform either a present user or a requesting user that another user has, or wants, access to the robot. The timeout mechanism gives certain types of users a prescribed amount of time to finish access to the robot. The queue mechanism is an orderly waiting list for access to the robot. The call back mechanism informs a user that the robot can be accessed. By way of example, a family user may receive an e-mail message that the robot is free for usage. Tables 1 and 2, show how the mechanisms resolve access request from the various users.

Table I

User	Access Control	Medical Record	Command Override	Software/Debug Access	Set Priority
Robot	No	No	Yes (1)	No	No
Local	No	No	Yes (2)	No	No
Caregiver	Yes	Yes	Yes (3)	No	No
Doctor	No	Yes	No	No	No
Family	No	No	No	No	No
Service	Yes	No	Yes	Yes	Yes

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Table II

	Requesting User					
	Local		Caregiver	Doctor	Family	Service
Current User	Local	Not Allowed	-Warn current user of pending user -Notify requesting user that system is in use - Set timeout	-Warn current user of pending user -Notify requesting user that system is in use - Set timeout=5m	-Warn current user of pending user -Notify requesting user that system is in use - Set timeout=5m - Call back	-Warn current user of pending user -Notify requesting user that system is in use - No timeout - Call back
	Caregiver	-Warn current user of pending user. -Notify requesting user that system is in use. - Release control	Not Allowed	-Warn current user of pending user -Notify requesting user that system is in use - Set timeout=5m - Queue or callback	-Warn current user of pending user -Notify requesting user that system is in use - Set timeout=5m	-Warn current user of pending user -Notify requesting user that system is in use - No timeout - Callback
	Doctor	-Warn current user of pending user -Notify requesting user that system is in use - Release control	-Warn current user of pending user -Notify requesting user that system is in use - Set timeout=5m	-Warn current user of pending user -Notify requesting user that system is in use - No timeout - Callback	-Notify requesting user that system is in use - No timeout - Queue or callback	-Warn current user of pending user -Notify requesting user that system is in use - No timeout - Callback
	Family	-Warn current user of pending user -Notify requesting user that system is in use - Release Control	-Notify requesting user that system is in use - No timeout - Put in queue or callback	-Warn current user of pending user -Notify requesting user that system is in use - Set timeout=1m	-Warn current user of pending user -Notify requesting user that system is in use - Set timeout=5m - Queue or callback	-Warn current user of pending user -Notify requesting user that system is in use - No timeout - Callback
	Service	-Warn current user of pending user -Notify requesting user that system is in use - No timeout	-Notify requesting user that system is in use - No timeout - Callback	-Warn current user of request -Notify requesting user that system is in use - No timeout - Callback	-Warn current user of pending user -Notify requesting user that system is in use - No timeout - Queue or callback	Not Allowed

The information transmitted between the station 16 and the robot 12 may be encrypted. Additionally, the user may have to enter a password to enter the system 10. A  
5 selected robot is then given an electronic key by the station 16. The robot 12 validates the key and returns another key to the station 16. The keys are used to encrypt information transmitted in the session.

Figure 10 shows a robot head 300 that can both pivot  
10 and spin the camera 38 and the monitor 40. The robot head 300 can be similar to the robot 12 but without the platform 210. The robot head 300 may have the same mechanisms and parts to both pivot the camera 38 and monitor 40 about the pivot axis 4, and spin the camera 38 and monitor 40 about  
15 the spin axis 5. The pivot axis may intersect the spin axis. Having a robot head 300 that both pivots and spins provides a wide viewing area. The robot head 300 may be in the system either with or instead of the mobile robot 12. The head 300 may be placed in a patient room to conduct  
20 two-way videoconferencing between a patient and a doctor at a remote location. The pivoting and spinning degrees of

freedom allow the doctor to move the camera to follow an ambulatory patient.

While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those ordinarily skilled in the art.